THE RESULTS OF AN AMBIENT AIR ASBESTOS MONITORING PROGRAM IN THE VICINITY OF AN INACTIVE REFUSE PILE IN AMBLER, PENNSYLVANIA

Prepared for

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I. INTRODUCTION

The primary sources of airborne asbestos are associated with the mining and manufacturing of asbestos. At a manufacturing facility, such as the plants operated in Ambler, Pennsylvania, asbestos enters the atmosphere from fugitive emission sources. These fugitive emissions usually consist of small, periodic releases, originating from various baghouse control devices, doorways and imperfect seals on contaminent areas, and asbestos particles from the surface layer of the active and inactive waste-disposal piles.

The inactive waste-disposal pile in the vicinity of the Nicolet Industries plant is a large, irregular-shaped mound, covering an area of approximately 10 acres. The major axis of the pile is oriented east-west. The pile was primarily created from the disposal of asbestos waste products manufactured at the Nicolet plant. The waste-disposal pile is composed primarily of calcium carbonate, asbestos, and other inorganic and organic materials.

Although the pile has remained inactive for about 7 years, it was utilized most recently as a disposal site for sewage sludge generated by a nearby waste-treatment plant. As a result, vegetative growth such as trees, grass, and shrubs now covers approximately 60 to 75 percent of the elevated surface area. The remaining surface area consists of relatively exposed, steep slopes around the periphery of the pile. As one would expect, the lack of vegetative cover for these exposed areas is primarily due to the steep slopes and high alkalinity of the material. An aerial view of the Nicolet plant and the inactive pile is shown in

Figure 1. The white areas of the photograph are the exposed slopes.

The exposed slopes, especially along the northern bank of the inactive waste-disposal pile, represent a potential area for fugitive asbestos emissions. Directly bordering the slopes of the northern bank is a community recreational area (i.e., basketball court and barbecue) and the adjacent properties of occupied dwellings. Because of the potential injurious effects from the inhalation of asbestos fibers, the Pennsylvania Department of Environmental Resources is concerned about the nonoccupational exposure of the local population in the vicinity of the inactive pile. Specifically, does the asbestos released from this inactive pile represent a hazard to public health?

To answer this question, the Pennsylvania Department of Environmental Resources (DER), Bureau of Air Quality and Noise Control, contracted Equitable Environmental Health, Inc. (EEH) to conduct a study to determine

1. if, and under what conditions, asbestos is released from the inactive refuse pile and transported to the adjacent residential community
2. the extent of community exposure to airborne emissions from the pile
3. to what extent, if possible, the other plant activities contribute to the ambient levels of asbestos.

To accomplish these objectives, EEH designed and conducted an intensive field monitoring program in the vicinity of the inactive pile. This report describes the results of the intensive monitoring survey and

includes a discussion of the design and operation of the field sampling program, a presentation of quantitative estimates of asbestos concentrations, and an evaluation of the ambient asbestos levels.

II. PROGRAM SUMMARY

During November 1976, an intensive monitoring program was undertaken to determine the levels of community exposure to airborne asbestos in the vicinity of the inactive refuse pile in Ambler, Pennsylvania. Monitoring stations were established to determine if other nearby asbestos sources contribute to nonoccupational exposure levels in the vicinity of the test area.

A total of 13 monitoring stations were established, and 123 samples were collected; 73 of those were analyzed for asbestos. The selection of samples was based primarily on meteorological conditions, condition of the pile, and maximum potential community exposure.

The samples were analyzed by Walter C. McCrone Associates, Inc. The analysis consisted of examination of the samples by optical (NIOSH phase-contrast) microscopy and transmission electron microscopy.

Of the 73 samples analyzed, only 4 samples had detectable levels of asbestos, of which only 2 could be attributed to the inactive pile. Following is a tabulation of the asbestos concentrations detected and the probable source:

Sampling Site	Asbestos Level (fibers/cubic centimeter)	Probable Source
C_1	0.017	Inactive pile
F_2	0.085	Plant activities
F_3	0.028	Plant activities
G_5	0.025	Plant, active pile, and inactive pile

The asbestos concentrations observed were extremely low and relatively infrequent.

III. PROGRAM APPROACH

The program was divided into two phases. The initial phase consisted of a preliminary survey designed to collect filter samples in order to establish the optimum dust-loading condition for each type of sampler. The second phase, the primary monitoring survey, was designed to obtain samples at preselected locations in the vicinity of the inactive pile for a 3-week period.

Based on previously established criteria for filter sample selection, various filters were analyzed to determine the asbestos concentrations. Next, the results of the filter analysis were reviewed and evaluated with respect to the existing meteorological conditions, the state of the pile, and the potential source(s) of asbestos.

A. PRELIMINARY MONITORING PROGRAM

Prior to the start-up of the primary monitoring program, it was necessary to establish the optimum dust-loading conditions because excessive loading of nonasbestos fiber would make the filter analyses extremely difficult and contribute to inaccurate estimates of asbestos fiber concentrations. At the same time, a sufficient volume of air had to be sampled to make the results statistically significant.

In order to determine the optimum volume of air to pass through each filter, seven sampling locations were established adjacent to and along the exposed slope of the inactive pile where it was anticipated that asbestos concentrations would be maximum. The total airflow through each sampler was varied from 1,000 to 8,500 liters. These

filter samples were then hand-carried to Walter C. McCrone Associates, Inc. for analyses. Upon examination, it was noted that samples obtained at a flow rate of 3,000 liters experienced minimal dust loading whereas samples obtained at flow rates exceeding 8,000 liters indicated excessive dust loading. Thus, it was decided that the total flow through each sampler would be maintained at 4,000 to 6,000 liters during the primary field monitoring program.

B. PRIMARY MONITORING PROGRAM

To meet the objective of the primary field monitoring program, five types of monitoring locations were established to meet the following criter

1. to determine background levels
2. to measure the maximum community exposure from the inactive refuse pile
3. to measure to the degree of stabilization over the vegetative surface of the pile
4. to measure the asbestos contribution from other sources
5. to determine the contribution of asbestos from the exposed surface of the pile.

As part of the monitoring instrumentation, a wind speed and wind direction recording system was installed on top of the inactive pile and mounted on a 10-foot mast, which was supported by a tripod. Data were collected on a continuous basis from November 1 through 18 without significant data loss. Descriptions of each monitoring site, site

selection criteria, and potential asbestos sources are listed in Table 1. The exact locations of the sites are shown in Figure 2.

In addition to the wind sensors installed on top of the inactive pile, supplemental meteorological data were obtained from the Naval Weather Service Office at the Willow Grove Naval Air Station in Horsham, Pennsylvania. The geographical relationship between the Ambler site and the air station is shown in Figure 3.

C. OPERATION OF THE FIELD MONITORING PROGRAM

The primary sampling program was operated from November 1 through 19, 1976. The nominal sampling period was usually from 0900 to 1500 hours EST during conditions that should have maximized the release of asbestos from the pile. During the primary program, samples were also obtained on a Sunday when both the Nicolet and Certain-Teed plants were closed. In addition, one group of samples was obtained during a 16-hour period from 1600 hours EST on October 18 to 0900 hours EST on October 19.

The air samples were collected on 47-millimeter Millipore membrane filters with an 8-micron pore size. The filter holders were placed in downward and located approximately 5 to 6 feet above ground. Depending on the type of sampler, the flow rate was set so that the total volume that passed through each filter ranged from 4,000 to 6,000 liters.

A total of 123 samples were obtained during the entire sampling program. The filters selected for analysis consisted of 68 collected during the primary program and 7 collected during the preliminary test program. The samples were shipped to Walter C. McCrone Associates, Inc. for analyses by optical and electron microscopy. The filters that were

Table 1

Location and Type of Asbestos Monitoring Sites

Site Identification	Description of Location	Site Selection Criteria	Potential Asbestos Source
A	Inside fence at northwest corner of pile on Locust Street	5	Inactive pile
B	Inside fence at base of pile on Locust Street	5, 2	Inactive pile
C	Inside fence at base of pile on Locust Street near basketball court	5, 2	Inactive pile
D	First house at southeast end of Locust Street	5, 2	Inactive pile
E	Center Street, 200 feet from Locust Street	5, 4	Inactive pile and plant
F	Nicolet property, northeast of Chestnut Street	4	Inactive pile and plant
G	Between active and inactive piles	4	Active pile and plant
H	North of Butler Pike adjacent to Wissahickon Creek	1	(Background site)
I	Top of pile	5, 3	Inactive pile
J	Fourth house from southeast end of Locust Street	5, 2	Inactive pile
K	Inside gate at end of Chestnut Street	4	Plant
L	Inside fence at base of pile on Locust Street	5, 2	Inactive pile
M	Inside fence at base of pile near south end of basketball court	5, 2	Inactive pile

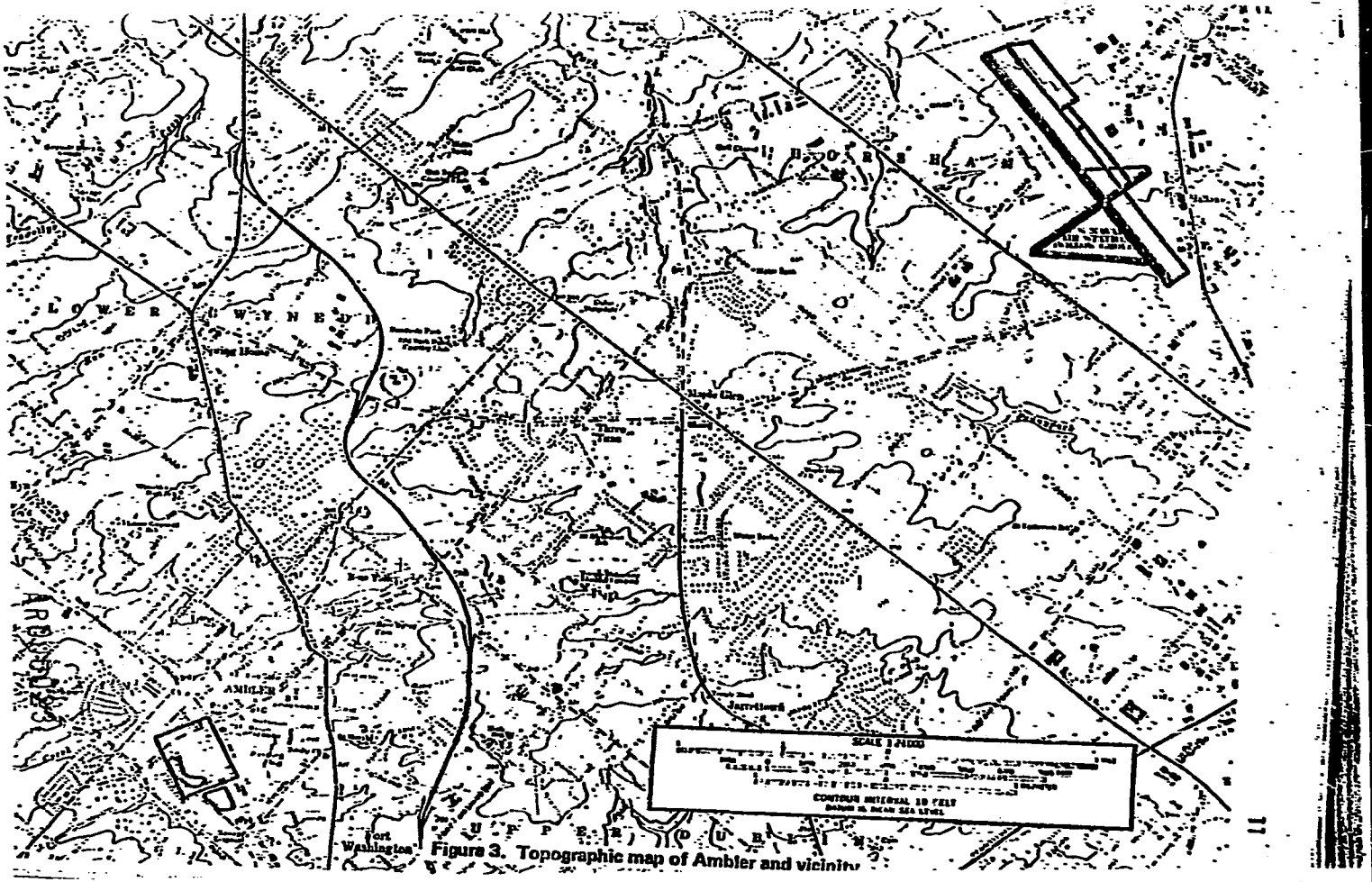


Figure 3. Topographic map of Ambler and vicinity

analyzed were selected on the basis of the maximum exposure potential to the local population along the northern bank of the pile. The selection criteria that were used were based on the daily meteorological conditions, i.e., relatively high wind speeds and favorable wind direction as well as proximity to possible sources of asbestos. In addition, the samples selected for analyses included the full representation of the five types of monitoring sites. A tabulation of the filters selected for analysis is presented in Table 2.

There were two types of air samplers used during the study: the DC battery-operated Research Appliance Company (RAC) midget air samplers and the AC-powered Unico-Gelman air sampler. The wind-monitoring system was a Wind Mark III manufactured by Climatronics Corporation. A technical description of this monitoring equipment is provided in Appendix A.

Prior to field use, the wind speed and wind direction system was wind-tunnel-tested and calibrated to determine accuracy, threshold, distance constant, and linearity. To ensure maximum data reliability and data recovery, static zero calibrations were performed daily on the electronics of the wind speed and wind direction processors in the field. A combination of static span and dynamic span calibrations was also performed daily on the electronics of the wind-direction processor. The static span calibration verified the proper operation of the electronics only, whereas the dynamic span calibration verified the proper operation of the entire wind direction sensor system. This was accomplished by physically orientating the wind direction vane toward a distant point of known azimuth.

The Research Appliance Company midget air samplers and the Unico-Gelman air samplers were both installed and operated daily at previously

Table 2

Filters Analyzed to Determine Asbestos Filter Counts

Location	Date	Average Wind Speed (mph)	Wind Direction
A-1	11-1	12	NW
A-3	11-3	5	SSW
A-4	11-4	5	W
B-1	11-1	12	NW
C-1	11-1	12	NW
D-1	11-1	12	NW
D-2	11-2	6	W
E-1	11-1	12	NW
E-2	11-2	6	W
E-3	11-3	5	SSW
E-4	11-4	5	W
F-1	11-2	6	W
F-2	11-3	5	SSW
F-3	11-4	5	W
F	10-28	8	WSW
G-1	11-2	6	W
G-2	11-3	5	SSW
G-3	11-4	5	W
H-2	11-3	5	SSW
H-3	11-4	5	W
I-2	11-3	5	SSW
I-3	11-4	5	W
J-1	11-3	5	SSW
J-2	11-4	5	W
K-1	11-8	10	NW
K-3	11-9	7	SW
K-4	11-10	11	WNW
A-6	11-8	10	NW
A-7	11-9	7	SW
E-6	11-8	10	NW
E-7	11-9	7	SW
E-8	11-10	11	WNW
F-5	11-8	10	NW
F-6	11-9	7	SW
F-7	11-9	11	WNW
G-5	11-8	10	NW
G-6	11-9	7	SW
G-7	11-10	11	WNW
H-5	11-8	10	NW
H-6	11-9	7	SW
H-7	11-10	11	WNW
J-4	11-8	10	NW
J-5	11-9	7	SW
J-6	11-10	11	WNW

Table 2 (Cont.)

Location	Date	Average Wind Speed (mph)	Wind Direction
A-10	11-14*	9	WSW
A-15	11-19	4	WSW
A-14	11-8	11	WNW
E-15	11-19	4	WSW
F-10	11-14*	9	WSW
F-14	11-18	11	WNW
G-10	11-14	9	WSW
G-14	11-18*	11	WNW
G-15	11-19	4	WSW
H-10	11-14*	9	WSW
H-13	11-18	11	WNW
I-13	11-18	11	WNW
J-9	11-14*	9	WSW
J-13	11-18	11	WNW
J-14	11-19	4	WSW
K-6	11-14*	9	WSW
K-10	11-18	11	WNW
K-11	11-19	4	WSW
L-3	11-18	11	WNW
M-3	11-18	11	WNW
M-4	11-19	4	WSW

In addition, six filters obtained on 10-28 were analyzed to determine the optimum dust loading to be utilized for the testing phase of the program.

* Sampling on Sunday; no plant operations.

selected locations. The pump, flow-control valve, and rotameter were placed on the ground within a protective enclosure. The filter holder assembly was mounted approximately 5 feet above the ground and was connected to the pump with surgical tubing.

The RAC midget air samplers were usually operated at 15 liters per minute for 5 hours, which yielded a total volume of about 4,500 liters through the filter medium. The Unico-Gelman air samplers were operated at about 25 liters per minute for 4 hours, which yielded 6,000 liters.

Prior to and after the use of a particular filter, rotameter readings of the initial and final flow rate were taken. In addition, the rotameters of all sampling units were calibrated with a high-accuracy wet-gas test meter and a stopwatch at both the start and completion of the field monitoring program. The time for 30 liters of air to pass through the rotameter was recorded as was the indicated reading of the rotameter. This was performed at three different rotameter settings to ensure linearity, and twice at each setting to insure reproducibility.

D. DESCRIPTION OF ANALYTICAL METHODS

All filters selected for analysis were analyzed by both electron and optical microscopy.

1. Optical Analyses

Optical analyses record all fibers that are more than 0.5 micrometers long and that have aspect ratios greater than 3. No attempt is made to identify the fibers or to confirm them as asbestos.

The examination by the NIOSH optical phase-contrast method yielded no fiber concentrations above 0.7 fibers per cubic centimeter; the levels were generally below 0.0055 fibers per cubic centimeter.

The results of the phase-contrast microscopy are presented in Appendix C, Tables C-1 through C-3. The analytical methods are detailed in Appendix B.

2. Transmission Electron Microscopy

The analyses of the filters by transmission electron microscopy (TEM) report the presence of all asbestos forms regardless of size. In addition, all fibers suspected of being asbestos are confirmed by electron diffraction. Examination by TEM revealed the presence of chrysotile asbestos in samples C-1, F-2, F-3, and G-5.

In general, the specimens contained chunky inorganic particles, small organic remains, small agglomerated material (exhibiting a chain-like structure), and spheroidal particles (Table C-4). Tables C-4 through C-6 present the results of the electron microscopy before corrections for calibrations of the samples. The lower limit of detection for each filter analyzed is also presented. The lower limit of detection corresponds to the fiber count if one fiber of asbestos was present in the filters analyzed. In addition, for each of the four filters that had identifiable asbestos fibers, computer printouts of the length, width, aspect ratio, and mass of each fiber are presented, along with descriptive statistical information, in Appendix C.

The TEM procedure is also detailed in Appendix B.

IV. PROGRAM RESULTS

A. RESULTS OF THE NIOSH PHASE-CONTRAST METHOD

The NIOSH sampling and analytical method used in the study was originally developed to determine the exposure levels of workers involved in the mining, manufacturing, and handling of asbestos minerals or products. It was assumed that the total fiber concentration in the working environment was primarily composed of asbestiform fibers. At present, there is an occupational asbestos standard based on the NIOSH sampling and analytical procedure. This standard is an 8-hour time-weighted average of 2 fibers per cubic centimeter (U.S. Dept. of Labor 1972). Although this standard and the analytical technique are not directly applicable for determining the concentration of airborne asbestos in the free atmosphere, filter samples can be analyzed by the NIOSH method to determine the magnitude of the fiber loading.

The results of the analysis of the filter samples that were collected during the study and analyzed by the NIOSH phase-contrast method are presented in this section. The optical counting technique (described in Appendix B) is not selective just for asbestiform fibers, but provides an estimate of the total particle concentration (in fibers per cubic centimeter) for all fibers longer than 5 microns.

The results are presented for comparative purposes only. In all, 48 of the 73 analyzed filters were obtained during a sampling period of 4 to 5 hours, which is comparable to NIOSH requirements. The mean total fiber concentration for all samples was only 0.006 fibers per cubic centimeter for particles with an aspect ratio of 3 and a length greater

than 5 microns. The range of observed fiber concentrations varied from a peak value of 0.066 at site G, to a low value of 0.0005 fibers per cubic centimeter at site D (Figure 3). These levels are extremely low as compared to the occupational standard; in this case, even the peak value is approximately two orders of magnitude less than the standard.

B. RESULTS OF THE TRANSMISSION ELECTRON MICROSCOPY

A transmission electron microscopy (TEM) analysis was performed to selectively determine the presence of asbestiform (chrysotile) fibers, including fibers less than 5 microns in length. The TEM procedure, which is described in Appendix B, also provides qualitative information on the type and size of other particles present on the filters. The detailed results of the filter analysis performed by Walter C. McCrone Associates, Inc. are presented in Appendix C.

In summary, the examination of all 73 filters selected for analysis by the TEM method revealed the presence of chrysotile asbestos particles on only four of the air sampler filters. The corrected total fiber concentration ranged from 0.017 to 0.085 fibers per cubic centimeter at site C and site F, respectively. Depending on the particle loading on each filter, the minimal detectable asbestos concentration determined by the TEM technique varied from 0.0010 to 0.0032 fibers per cubic centimeter. The chrysotile asbestos particles usually appeared as single fibers, or in bundles or small groups with an unidentified binding material, or both. In general, other materials most frequently observed in the samples consisted of chunky inorganic particulates, small organic

particles, small agglomerate material (sometimes exhibiting a chainlike structure), and spheroidal particles (possibly fly ash). The total asbestos fiber concentrations and other pertinent information are provided in Table 3.

C. EVALUATION OF ASBESTOS CONCENTRATION DATA

Because of the limited number of filters with detectable levels of asbestos fibers, the data evaluation that was originally envisioned has been modified. Specifically, it was not possible to provide or develop actual or projected asbestos concentration patterns in the vicinity of the inactive refuse pile based on only four measurable concentrations at only three sampling locations. Other graphical presentations, such as asbestos (pollutant) wind roses and fiber concentrations as a function of distance from the pile, were also considered impractical. However, an attempt was made to review and evaluate all data obtained during the intensive monitoring survey and to understand the relationship between (1) the measured ambient asbestos levels and (2) the meteorological conditions and existing physical condition of the inactive refuse pile. In addition, the asbestos levels measured during the field sampling program were compared to the ambient asbestos concentrations obtained during a previous study in the vicinity of the inactive refuse pile in Ambler, Pennsylvania.

1. Existing Conditions

a. Meteorology

The intensive field monitoring survey was conducted during the first

Table 3

Observed Asbestos Chrysotile Fiber Concentration Data
in the Vicinity of the Inactive Refuse Pile, Ambler, Pennsylvania

Site	Date (1976)	Sampling Period	Type of Sampler	Total Volume of Air (liters)	Total Asbestos Fiber Concentration[a] (fibers/cubic centimeter) Initial	Final
C-1	Nov. 1	1132 to 1555	Research Appliance Company	3,419	0.016	0.017
F-2	Nov. 3	1058 to 1411	Unico-Gelman	5,211	0.069	0.085
F-3	Nov. 4	0959 to 1358	Unico-Gelman	6,120	0.023	0.028
G-5	Nov. 8	0954 to 1402	Unico-Gelman	6,696	0.025	0.0306

a. The initial and final total asbestos fiber concentrations are based on the calibration of the sampler rotameter at the start of and completion of the monitoring program.

3 weeks of November 1976. November is normally characterized as a transition period in eastern Pennsylvania, with relatively mild days (afternoon temperatures in the mid- to upper 50s) and cool nights (temperatures into the low 40s). It is not unusual, however, for the first indications of winter to occur during this month, with raw, cold days. The average monthly precipitation total for November in the Philadelphia area is 3.3 inches, which is equivalent to the annual monthly average.

The weather patterns during November 1976 featured a strong, upper-level northwesterly to westerly flow over the area. Although frontal systems traversed the area frequently, the accompanying cyclonic disturbances and the major precipitation activity occurred primarily to the north or south of the region. In response to this abnormally cold, dry, persistent airflow, the Delaware Valley experienced one of the coldest driest Novembers in recent history.

An average monthly temperature of 39.9° F was observed at the Philadelphia International Airport, which was 7.3° F below normal, the second coldest November on record. The monthly precipitation, measured at both Philadelphia and Willow Grove, established new records as the driest November. Precipitation for the month totaled 0.32 and 0.51 inches in Philadelphia and Willow Grove, respectively. Measurable precipitation was observed on only 2 days during the field program, i.e., during the evening hours of November 3 and 5, when rainfall amounted to 0.03 and 0.07 inches, respectively.

The prevailing surface wind direction that was measured on top of the inactive refuse pile throughout the monitoring program was primarily from the western quadrant. The frequency of occurrence of westerly winds

observed at the monitoring site is quite evident and is illustrated by the wind polygon in Figure 4. The degree of correspondence between the wind directions recorded at the Ambler and Willow Grove locations suggests that the general exposure of the sites and local micrometeorological conditions experienced at each site are comparable.

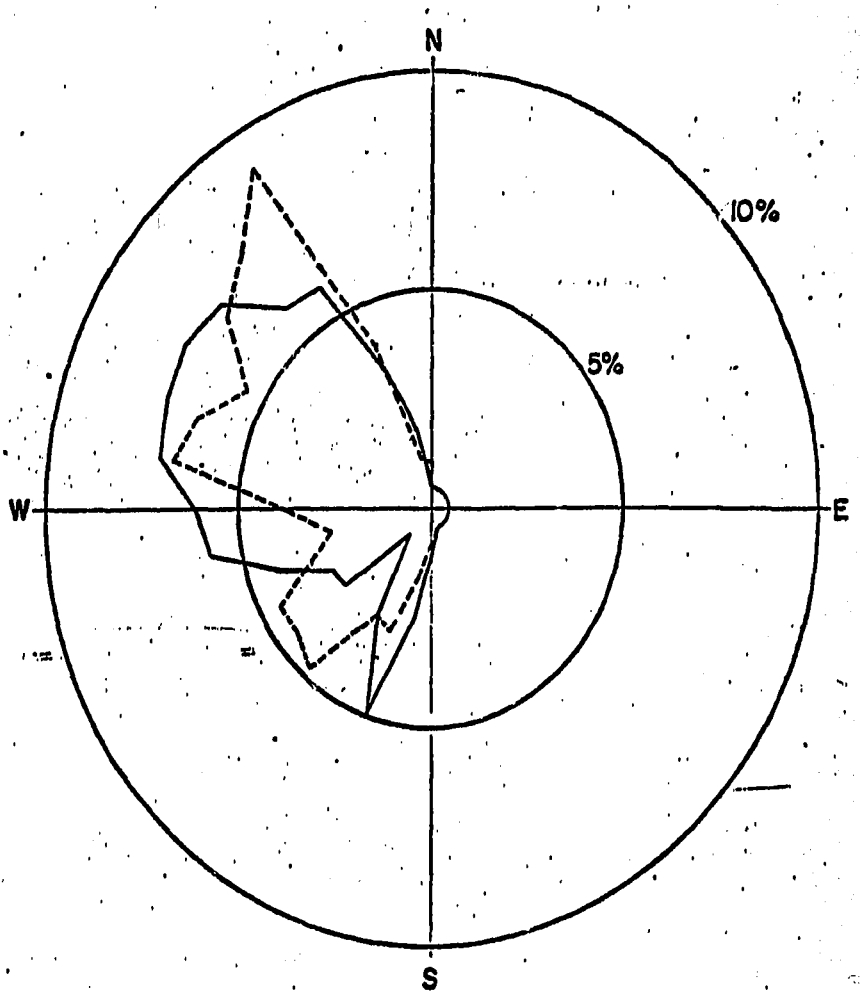
Average wind speeds measured during the nominal sampling periods (0900 to 1500) varied from about 4 to 12 miles per hour. At night, winds were generally light, with an average speed of less than 3 miles per hour.

b. State of the Inactive Refuse Pile

To assess the condition of the exposed surface area of the pile, visual and tactual observations were made daily at the monitoring sites adjacent to the pile. These qualitative observations were necessary to determine if the exposed areas of the pile were an active or passive emission source.

Although unseasonably cool, dry weather conditions prevailed throughout most of the monitoring program, significant precipitation occurred on October 30 and 31. During these 2 days, 0.63 inches of rain were recorded at the Willow Grove Naval Air Station. As a result, the exposed surface areas of the pile were very moist, with standing pools of water present at the base of the pile.

Because of the subsequent precipitation on November 3 and 5, accompanied by relatively cool temperatures, the pile remained in a moist condition during the first 5 days of the sampling program. The lack of measurable precipitation, combined with the relatively high wind speeds after November 5, contributed to conditions that enhanced the evaporative



——— Ambler, Pennsylvania (inactive pile, meteorological site)

– – – – – – Willow Grove Naval Air Station, Horsham, Pennsylvania

Figure 4. Wind frequency diagram (in percent).

processes and reduced the moisture content of the surface layer of the pile.

Within a few days, the surface layer of the exposed slopes appeared relatively dry to a depth of 1 to 2 centimeters, but a thin, cracked crust had formed and covered the entire exposed surface area. However, the presence of moisture was still evident, especially on days with subfreezing temperatures. On these days, portions of the surface layer and subsurface were frozen, which caused the material within the surface layer to adhere to ice crystals. The diurnal freezing and melting of the ice during the day caused the surface layer to expand and contract, which created the thin crust over most of the exposed surface. On visual inspections of the pile, individual chrysotile fibers were readily evident on portions of the exposed surface. Throughout the entire monitoring program, however, no visible emissions in the form of dust clouds were observed above the surface.

2. Analysis of Asbestos Concentration Data

In general, the meteorological conditions that were encountered during the asbestos sampling program should have maximized or enhanced the release of material from the exposed surfaces of the inactive pile. Specifically, these conditions were

1. absence of measurable precipitation during the monitoring program
2. favorable prevailing wind direction (the windflow at oblique angles or nearly parallel to the orientation of the northern bank)
3. relatively high wind speeds during the sampling periods.

With these conditions present, detectable asbestos fiber concentrations were determined on only 4 of the 73 analyzed filters. These ambient asbestos levels were measured at three different monitoring sites in the vicinity of the pile. These sites, sampling periods, and the corresponding meteorological conditions are listed in Table 4. The actual monitoring locations and plant emission points are identified in Figure 5.

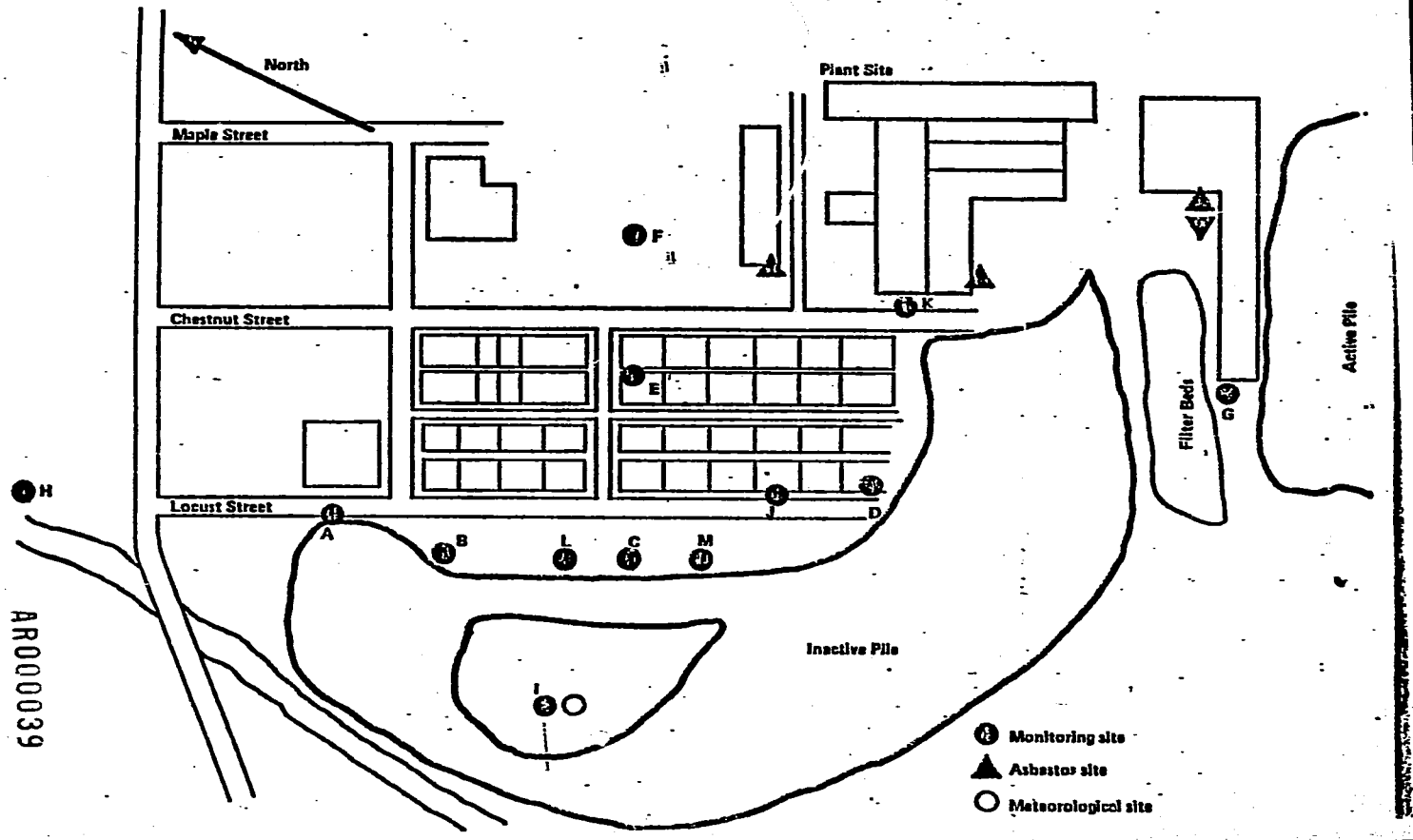
Nine of the sampling locations were specifically designed to measure the asbestos contribution from the inactive pile. However, detectable asbestos concentrations were obtained at only one site, site C. It is interesting that the measurable asbestos concentration obtained at site C occurred the day after a heavy rainfall. Apparently, the primary factor contributing to the measurable asbestos level at site C was the relatively high wind speeds. One of the highest average daily wind speeds (7.5 miles per hour) was recorded on November 1, 1976. Although comparable meteorological conditions (but with slightly lower wind speeds) were observed on at least two subsequent sampling days, no detectable asbestos levels were measured.

The detectable asbestos concentrations obtained at site F on November 3 and 4 appear to be related to nearby plant emission sources. Because of the relatively low average wind speeds (less than 4 miles per hour) and a windflow generally from the south to southwest that persisted throughout November 3 and 4, any asbestos released at the plant site would have been poorly dispersed and slowly transported to the monitoring location (Figure 5). It is doubtful that the ambient asbestos levels observed at site F were associated with fugitive asbestos emissions from the inactive pile.

Table 4

Meteorological Conditions During Sampling Periods of Detectable Asbestos Concentrations

Date (1976)	Site	Sampling Period	Winds	Temperature (°F) Maximum	Temperature (°F) Minimum	Precipitation
Nov. 1	C-1	1132 to 1555	315° to 325° at 11 to 13 mph, with gusts from 18 to 20 mph	43	36	None
Nov. 3	F-2	1058 to 1411	210° to 190° at 3 to 6 mph	51	39	None
Nov. 4	F-3	0959 to 1358	Light and variable, then 230° to 270° at 3 to 5 mph	56	31	None
Nov. 8	G-5	0954 to 1402	320° to 335° at 11 to 14 mph, with gusts to 22 mph	36	30	Widely scattered snow showers


North
Maple Street
Chestnut Street
Locust Street
Plant Site
Filter Beds
Active Pile
Inactive Pile
F
K
E
H
A
B
L
C
M
D
I
Monitoring site
Asbestos site
Meteorological site

It is difficult to determine the asbestos source that contributed to detectable asbestos concentrations at site G on November 8. Based on the observed meteorological conditions, it appears that the measured asbestos level at site G may represent a portion of the total asbestos burden released from inactive and active piles as well as from the various plant emission sources. Upon review of the data, it was found that, except for lower ambient temperatures, the meteorological conditions observed on November 8 were quite similar to the conditions observed on November 1. However, no measurable asbestos levels were determined at any of the monitoring locations that are in close proximity to the exposed northern bank of the inactive pile.

D. CONCLUSIONS AND RECOMMENDATIONS

Most of the samples collected did not have detectable levels of asbestos; therefore, it was impossible to document or test the statistical extent of the community exposure to asbestos that originates from the inactive pile. Detectable asbestos levels were only observed at one location adjacent to the inactive pile and the local community. Approximately half of the 73 analyzed filters were collected at monitoring sites at or near the playground and near various residential dwellings along Locust Street. The lack of measurable asbestos levels in the vicinity of the pile may indicate that the pile is sufficiently stabilized so that fugitive emissions are negligible or infrequent.

The magnitude and extent of ambient asbestos concentrations measured during the November 1976 monitoring program are comparable to ambient asbestos levels determined by the U.S. Environmental Protection Agency at the Ambler location during October 1973. The results of the previous

study (EPA 1974) and the latest sampling results are summarized in Table 5. The ambient asbestos levels are presented in terms of an average weight concentration (nanograms per cubic meter). The monitoring locations where the EPA samples were collected were similar to the EEH monitoring sites. Although the EPA's sampling duration (sampling time for each filter) was greater than EEH's, the average asbestos concentrations obtained by the EPA at the three monitoring sites were similar to EEH's results. The asbestos concentrations observed by the EPA at site G were directly attributable to asbestos emissions associated with a disposal operation at the active pile site. This asbestos-disposal procedure was terminated in 1974.

The implication of the results of the previous study, together with the most recent sampling data, suggests that fugitive asbestos emissions from the exposed surfaces of the inactive pile are insignificant and infrequent. Furthermore, the results indicate that measurable asbestos levels in the vicinity of the inactive pile, in some cases, may be independent of the condition of the pile. For example, detectable levels were observed when the exposed surface of the pile was moist. Detectable levels were only observed at sampling locations adjacent to the active and inactiv piles in combination with average daily wind speeds in excess of 7.5 miles per hour and with a wind direction from the northwest. At relatively low wind speeds and with a persistent southerly flow, the periodic releases of asbestos from the plant facilities can reach detectable levels.

One final point should be addressed. Although the evidence indicates that fugitive asbestos emissions from the pile and the resulting ambient

Table 5

Summary of Ambient Asbestos Concentrations Measured in Ambler, Pennsylvania

A. EEH MONITORING PERIOD, NOVEMBER 1 TO 19, 1976

Site	Nominal Sampling Time (hours)	No. Samples	Average Asbestos Concentration (nanograms/cubic meter)
C	5	1	<1
F	4	2	36
G	4	1	2

B. EPA MONITORING PERIOD, OCTOBER 15 TO 18, 1973

Site	Nominal Sampling Time (hours)	No. Samples	Average Asbestos Concentration (nanograms/cubic meter)
C(8)[a]	12	2	10
F(9)	12	3	21
G(7)	12	1	>1,200

a. Numbers in parentheses are EPA site identification numbers.

concentrations are extremely low, wind conditions and the lack of significant precipitation existed during the monitoring program that should have maximized the asbestos contribution from the inactive pile. However, it is possible that the below-freezing temperatures that occurred on all but four of the sampling days (November 1, 4, 5, 7) may have caused a reduction in the emissions of the pile. Only 2 of the 73 samples analyzed had measurable asbestos levels that may have originated from the pile. Detectable asbestos levels were determined on filters collected on the day that, or the day after, above-freezing temperatures were observed.

Based on the results of the study, EEH recommends that a follow-up monitoring study should be conducted this summer (June, July, or August 1977). Sampling should be performed at the monitoring sites adjacent to the pile for 2 to 3 days. The primary purpose of this monitoring effort would be to verify that the results obtained by the EEH field program are indeed the maximum emissions emanating from the pile.

REFERENCES

U.S. Department of Labor. 1972. Washington Information Document. T2-366.

U.S. Environmental Protection Agency. 1974. Background Information on National Emission Standards for Hazardous Air Pollutants--Proposed Amendments to Standards for Asbestos and Mercury. EPA-450/2-74-009a. Research Triangle Park, North Carolina.

APPENDIX A

DESCRIPTION OF INSTRUMENTATION

1. TEST EQUIPMENT

The two types of air samplers that were used are a Unico-Gelman air-sampling kit and a midget air sampler manufactured by Research Appliance Company (RAC). Each unit is equipped with a valve that enables the user to vary the sampling flow rate. The flow rate is read directly by a rotameter that is integral with the units.

The Unico-Gelman unit has a free-air capacity of 2.4 cubic feet per minute (68 liters per minute) and is operated by a 115-volt, 60 Hz power supply. The RAC unit has a free-air capacity of 19 liters per minute and is operated by a 12-volt automotive battery.

2. WIND SPEED AND DIRECTION SYSTEM--CLIMATRONICS WIND MARK III

The wind-speed sensor, a stainless-steel, three-cup anemometer, generates an electrical signal by a photochopper that uses a solid-state light source for maximum reliability. The wind-direction sensor is a counterbalanced vane that is coupled to a precision potentiometer. Both wind-speed and wind-direction transmitters use stainless-steel, precision ball bearings for maximum life and low threshold.

Wind speed and wind direction are recorded on a dual-channel recorder with a recording width of 2.3125 inches per channel. The recorder can be operated in the tear-off mode or in the reroll mode.

The system is operated by a battery power supply. Technical specifications for the Wind Mark III system follow.

Wind Mark III Specifications

Wind Speed	
Accuracy	Sensor: ±0.25 mph or 1.5 percent System: ±0.5 mph or 2 percent
Range	0-50 and 0-100 mph
Distance constant	8 feet maximum
Threshold	0.75 mph
Wind Direction	
Accuracy	Sensor: ±5° System: ±2°
Range	0°-360° mechanical; 0° to 540° electrical
Distance constant	8 feet maximum
Damping ratio	0.4-0.6
Threshold	0.75 mph

APPENDIX B

DESCRIPTION OF ANALYTICAL PROCEDURES FOR PERFORMING FIBER COUNTS

1. OPTICAL MICROSCOPY

The concentration of fibers longer than 5 micrometers was determined by the use of a phase-contrast illumination microscope, as recommended by NIOSH.

The mounting medium used was prepared by dissolving 0.05 grams of membrane filter per milliliter of 1:1 solution of dimethyl phthalate and diethyl oxalate. A drop of mounting solution was placed on a clean microscope slide. A quadrant was cut from the filter and placed, exposed surface-upward, on the drop of mounting solution by touching one corner down onto the slide and then allowing the drop to spread evenly under the filter as the filter was lowered on the slide. The preparation was then covered with a microscope cover glass. After approximately 10 to 15 minutes, the filter was completely cleared and was ready for examination.

The prepared filters were examined with a Cooke Troughton and Simms phase-contrast microscope using a 4-millimeter objective lens and 10X oculars in a binocular head, giving an overall magnification of approximately 400X. A graticule in one of the eyepieces permits calibration of particle sizes. All particulates having an aspect ratio greater than 3 to 1 and a length in excess of 5-micrometers were counted as fibers. Counting was continued until at least 100 fibers had been counted, but always with a minimum of 20 fields examined.

Calculation of the fiber concentration was based on the following formula:

$$f = \frac{A}{ka} \times \frac{N}{V}$$

where f = fibers per milliliter

A = area of filter

k = number of fields examined

a = area of field of view (in the same units as A)

N = number of fibers counted

V = volume of air sampled (milliliters).

It should be noted that no attempt was made to identify the fibers counted. Table B-1 is a tabulation of the results obtained by the optical microscopy.

2. ELECTRON MICROSCOPY

The samples were collected on membrane filters with a pore size of 0.8 micrometers. A section of the filter, approximately 4 millimeters in diameter, was placed facedown on a carbon-coated electron microscope grid. The membrane filter was dissolved, using acetone in a soxhlet extractor.

McCrone Associates has shown that there is very little risk of contamination in transferring the filter in the electron microscope grid to the soxhlet extractor. Furthermore, by dissolving the filter in situ on the grid, the risk of losing portions of the sample is minimal. Techniques involving transfer of a liquid suspension directly to the electron

microscope grid are more subject to error since there is frequently a size separation as the meniscus of the drying drop recedes.

The sample grids were examined on the electron microscope (JEM 200), using a magnification in which the intermediate lens aperture was in focus in the specimen plane. It was thus possible, by inserting the aperture and switching to the diffraction position, to obtain a selected area electron diffraction (SAED) pattern of the fiber with no other adjustments to the microscope. In this way, it was possible to spot-check the diffraction pattern of individual fibers very rapidly.

The electron microscopy was done at a relatively low power, 2,000X, with an optical aid of 1.5X optical magnifier (total magnification: 3,000X) or a 10X binocular dissection microscope (total magnification: 2,000X). Chrysotile asbestos fibers were resolved by the JEM electron microscope at 2,000X magnification and were visible on the screen with the aid of 1.5X or 10X optical magnification. For positive identification, 20,000X magnification was used for the morphology and electron diffraction of the fibers. If there was any doubt regarding the presence of fibrils, a field was scanned at 20,000X magnification with additional optical magnification of 10X (total: 2,000X) or 1.5X (total: 30,000X). The advantage of counting using the microscope viewing screen at a lower magnification is the greater field size; hence, a greater total area can be counted conveniently, giving a greater degree of statistical confidence.

The length and width of each asbestos fiber were recorded. Interpolation from intervals scribed on the screen allows an accuracy of measurement on the screen of approximately ±0.05 centimeters. This corresponds to an accuracy in size measurement of about 0.02 to 0.03 micrometers.

Measurements of the individual fibers are computer-processed to give listings of the length and width of the fibers, together with a computed mass of each fiber computed on the basis of density, D, and dimensions, L and W ($D \times L \times W^2$). A density of 2.3 was used for chrysotile.

A computer printout of the following information is presented for each filter that contained chrysotile asbestos.

1. calculated number of fibers per unit volume
2. calculated mass of fibers per unit volume
3. the size distribution of the fibers based on length and width, and the distribution of fibers by aspect ratio.

APPENDIX C

RESULTS OF FILTER ANALYSIS BY WALTER C. McCRONE ASSOCIATES, INC.

Table C-1

Results of NIOSH Phase-Contrast Examination

Sample	Fibers/Cubic Centimeter
A-1	0.0012
A-3	0.0021
A-4	0.0017
B-1	0.0011
C-1	0.0023
D-1	0.0005
D-2	0.0005
E-1	0.0011
E-2	0.0009
E-3	0.0021
E-4	0.0015
F-1	0.0008
F-2	0.0020
F-3	0.0010
G-1	0.0005
G-2	0.0656
G-3	0.0053
H-2	0.0029
H-3	0.0021
I-2	0.0046
I-3	0.0019
J-1	0.0011
J-2	0.0013

Table C-2

Results of NIOSH Phase-Contrast Examination

Sample	Fibers/Cubic Centimeter
A-10	0.0022
A-14	0.0751
A-15	0.0236
E-15	0.0270
F-10	0.0019
F-14	0.0339
F-15	0.0230
G-10	0.0013
G-14	0.0202
G-15	0.0191
H-10	0.0031
H-14	0.0369
I-9	0.0026
I-13	0.0444
J-9	0.0012
J-14	0.0395
J-14	0.0254
K-6	0.0008
K-11	0.0397
K-11	0.0285
L-4	0.0632
M-3	0.0658
M-4	0.0421

Table C-3

Results of NIOSH Phase-Contrast Examination

Sample	Fibers/Cubic Centimeter
A-6	0.0025
A-7	0.0026
E-6	0.0030
E-7	0.0028
E-8	0.0020
F-5	0.0055
F-6	0.0029
F-7	0.0071
G-5	0.0012
G-6	0.0017
G-7	0.0026
H-5	0.0564
H-6	0.0019
H-7	0.0023
I-5	0.0017
I-6	0.0112
J-4	0.0030
J-5	0.0023
J-6	0.0279
K-1	0.0259

Table C-4

Results of Analysis by Transmission Electron Microscopy of Group I

Sample	Lower Limit of Detection (fibers/cubic centimeter)	Asbestos Level Detected (fibers/cubic centimeter)	Comments
A-1	0.0029	BDL[a]	Mainly organic remains with sm inorganic particles present. asbestiform material detected.
A-3	0.0032	BDL	Varying small bits and pieces organic material are present. Chunky inorganics range to mod ate sizes. Agglomerated sampl material occurs in large sizes Some filmy residues noted. No asbestiform material detected.
A-4	0.0029	BDL	Little material of any signifi cance present. Very small chu inorganics, organic remains, a some large chunky inorganic pa ticles make up this sample. N asbestiform material detected.
B-1	0.0029	BDL	Chunky inorganic material make up most of this sample and ranges to very large sizes. Small organic remains are pres ent. No asbestiform material detected.
C-1	0.0027	0.016[b]	Inorganic particles of a gener ally chunky nature are present ranging to large sizes. Some agglomerated inorganics are pr ent. Most of the smaller material consists of organic remains. Occasional chrysotil fibers noted.
D-1	0.0013	BDL	Organic particles of varying types are present as are chunk inorganic particles ranging to sizes of 2 micrometers with on a small proportion being large No asbestiform material detect

a. BDL = Below detection limits.
b. Chrysotile.

Table C-4 (Cont.)

Sample	Lower Limit of Detection (fibers/cubic centimeter)	Asbestos Level Detected (fibers/cubic centimeter)	Comments
D-2	0.0012	BDL	Small to moderately large chunky inorganics, some fine agglomerated material, and small organic remains are present in this specimen. No asbestiform material detected.
E-1	0.0014	BDL	Chunky inorganic material is quite common and ranges to quite large sizes. A fine agglomerated material is present in addition to much small inorganic matter. No asbestiform material detected.
E-2	0.0016	BDL	Small chunky inorganic material, fine agglomerated particles, organic remains, and some quite large, chunky inorganic material are present in this specimen. No asbestiform material detected.
E-3	0.0025	BDL	Chunky inorganic material is present, ranging from submicrometer to large multimicrometer sizes. Varying types of organic remains are present. Some agglomeration of sample material noted. No asbestiform material detected.
E-4	0.0017	BDL	Small chunky particles, fine chainlike agglomerates, small organic remains, some organic fibers, and large chiplike or chunky inorganic particles constitute this sample. No asbestiform material detected. Occasional spheroidal particles noted.
F-1	0.0010	BDL	Organic remains are present in the smaller size ranges. Some fine agglomerated material is to be noted as well as occasional spheroidal particles. Inorganics present are generally chunky in

Table C-4 (Cont.)

Sample	Lower Limit of Detection (fibers/cubic centimeter)	Asbestos Level Detected (fibers/cubic centimeter)	Comments
F-1 (Cont.)			nature and range from very sm submicrometer sizes to the largest particles present. No asbestiform material detected.
F-2	0.0031	0.069[b]	Various types of organic remains and chunky inorganics ar present, ranging to moderate sizes. Chrysotile is present in bundles or small groups of fibers, which show a binding material. Counting the small groups is sometimes difficult due to the binding medium. Sc very large inorganic particula are present.
F-3	0.0018	0.023[b]	Small to quite large chunky in organics of varying type, smal organic remains, some agglomer ates, occasional spheroidal pa ticles, and chrysotile fibers are present.
G-1	0.0011	BDL	Chunky inorganics of varying size, fine agglomerated materi various types of organic remai and some spheroidal material a present in this sample. No asbestiform material detected.
G-2	0.0021	BDL	Small to quite large chunky or chiplike inorganic particles, spheroidal particles, agglomer ated material, organic remains and organic fibers are present No asbestiform material detect
G-3	0.0017	BDL	Small to quite large inorganic particles of a generally chunk nature, organic remains, organ fibers, some agglomerated fine material and occasional sphero dal inorganic particles are present. No asbestiform mater detected.

Table C-4 (Cont.)

Sample	Lower Limit of Detection (fibers/cubic centimeter)	Asbestos Level Detected (fibers/cubic centimeter)	Comments
H-2	0.0032	BDL	Chunky material to large sizes, fine chainlike agglomerates, organic remains, and some spheroidal particles are noted. No asbestiform material detected.
H-3	0.0028	BDL	Small to quite large chunky particulates, small organic remains, and some organic fibers are present. Distribution of material is somewhat uneven. No asbestiform material detected.
I-2	0.0032	BDL	Small to very large chunky inorganic material is the dominant feature of this specimen. Some chiplike inorganics, small organic remains, and large organic fibers are also present. No asbestiform material detected.
I-3	0.0027	BDL	Small to very large inorganic particles with morphologies ranging from chunky to agglomerate types are the major components of this sample. Some organic remains, large organic fibers, and infrequent large nonasbestos inorganic fibers are also present. No asbestiform material detected.
J-1	0.0018	BDL	Small to large sizes of inorganics of a generally chunky nature predominate. Small organic remains and small to moderately sized agglomerated material are present. No asbestiform material detected.
J-2	0.0014	BDL	Small to quite large chunky inorganic material, a fine agglomerate material, some spheroidal material, and small organic remains are present. No asbestiform material detected.

Table C-5

Results of Analysis by Transmission Electron Microscopy of Group II

Sample	Lower Limit of Detection (fibers/cubic centimeter)	Asbestos Level Detected (fibers/cubic centimeter)
A-6	0.0027	BDL[a]
A-7	0.0029	BDL
E-6	0.0016	BDL
E-7	0.0018	BDL
E-8	0.0017	BDL
F-5	0.0017	BDL
F-6	0.0018	BDL
F-7	0.0017	BDL
G-5	0.0017	0.025[b]
G-6	0.0018	BDL
G-7	0.0017	BDL
H-5	0.0024	BDL
H-6	0.0028	BDL
H-7	0.0029	BDL
I-5	0.0026	BDL
I-6	0.0028	BDL
J-4	0.0016	BDL
J-5	0.0018	BDL
J-6	0.0016	BDL
K-1	0.0018	BDL

a. BDL = Below detection limits.
b. Chrysotile.

Table C-6

Results of Analysis by Transmission Electron Microscopy of Group III

Sample	Lower Limit of Detection (fibers/cubic centimeter)	Asbestos Level Detected (fibers/cubic centimeter)
A-10	0.0031	BDL[a]
A-14	0.0024	BDL
A-15	0.0023	BDL
E-15	0.0012	BDL
F-10	0.0016	BDL
F-14	0.0017	BDL
F-15	0.0012	BDL
G-10	0.0016	BDL
G-14	0.0016	BDL
G-15	0.0011	BDL
H-10	0.0029	BDL
H-14	0.0019	BDL
I-9	0.0031	BDL
I-13	0.0025	BDL
J-9	0.0015	BDL
J-14	0.0012	BDL
J-14	0.0017	BDL
K-6	0.0016	BDL
K-11	0.0015	BDL
K-11	0.0012	BDL
L-4	0.0026	BDL
M-3	0.0022	BDL
M-4	0.0023	BDL

a. BDL = Below detection limits.

SAMPLE : G5 11/8/76 (CHRYSOTILE)

FIBER CONCENTRATION BY NUMBER PER CUBIC METER : 0.25E+05
FIBER CONCENTRATION BY MASS, PER CUBIC METER : 0.002 GRAMS*10+-6
AIR VOL. : 6696.0 LITERS
GRID SQUARES COUNTED : 60

DESCRIPTIVE STATISTICS

NO. OBS. = 15

VARIABLE	MEAN	VARIANCE	STANDARD DEVIATION	STANDAI ERROR
1 LENGTH	0.18129E+01	0.12956E+02	0.35995E+01	0.92939E
2 WIDTH	0.72333E-01	0.18026E-02	0.42457E-01	0.10962E
3 ASPECT RATIO	0.19769E+02	0.51965E+03	0.22796E+02	0.58859E
4 MASS	0.70093E-01	0.49166E-01	0.22173E+00	0.57251E

	SKEWNESS	KURTOSIS	MAX	MIN	RANGE
1	0.29021E+01	0.73829E+01	0.14524E+02	0.24210E+00	0.14282E+02
2	0.77094E+00	-0.85125E+00	0.16140E+00	0.28200E-01	0.13320E+00
3	0.20071E+01	0.32282E+01	0.90000E+02	0.43333E+01	0.85667E+02
4	0.31113E+01	0.82967E+01	0.87000E+00	0.40000E-03	0.86960E+00

SAMPLE : G5 11/8/76 (CHRYSOTILE)

	LENGTH	WIDTH	ASPECT RATIO	MASS
1	2.1383	0.0605	35.3333	0.0180
2	0.4035	0.0403	10.0000	0.0015
3	14.5243	0.1614	90.0000	0.8700
4	0.4841	0.0282	17.1429	0.0009
5	1.0490	0.1009	10.4000	0.0245
6	0.5245	0.1210	4.3333	0.0177
7	0.2421	0.0282	8.5714	0.0004
8	2.9049	0.0605	48.0000	0.0245
9	0.6455	0.0605	10.6667	0.0054
10	0.6859	0.0403	17.0000	0.0026
11	0.2824	0.0403	7.0000	0.0011
12	0.3631	0.0605	6.0000	0.0031
13	0.8876	0.1412	6.2857	0.0407
14	1.6945	0.1009	16.8000	0.0396
15	0.3631	0.0403	9.0000	0.0014

SAMPLE ,F2 (CHRYSOTILE)

FIBER CONCENTRATION BY NUMBER PER CUBIC METER : 0.69E+05
FIBER CONCENTRATION BY MASS, PER CUBIC METER : 0.072 GRAMS*10↑-6
AIR VOL. : 52.1.0 LITERS
GRID SQUARES COUNTED : 40

DESCRIPTIVE STATISTICS

NO. OBS. = 22

	VARIABLE	MEAN	VARIANCE	STANDARD DEVIATION	STANDAF ERROR
1	LENGTH	0.32258E+01	0.18092E+02	0.42535E+01	0.90685E
2	WIDTH	0.20998E+00	0.42000E-01	0.20494E+00	0.43693E
3	ASPECT RATIO	0.19131E+02	0.42297E+03	0.20566E+02	0.43847E
4	MASS	0.10428E+01	0.10289E+02	0.32076E+01	0.68387E

	SKEWNESS	KURTOSIS	MAX	MIN	RANGE
1	0.30540E+01	0.96352E+01	0.20576E+02	0.56480E+00	0.20011E+02
2	0.26595E+01	0.76306E+01	0.10086E+01	0.40300E-01	0.96830E+00
3	0.19561E+01	0.30425E+01	0.85000E+02	0.41667E+01	0.80833E+02
4	0.38166E+01	0.13798E+02	0.15105E+02	0.21000E-02	0.15102E+02

SAMPLE ,F2 (CHRYSOTILE)

	LENGTH	WIDTH	ASPECT RATIO	MASS
1	6.4553	1.0086	6.4000	15.1046
2	0.7262	0.1210	6.0000	0.0245
3	1.3717	0.1614	8.5000	0.0822
4	2.6224	0.1210	21.6667	0.0984
5	0.6455	0.1009	6.4000	0.0151
6	1.0086	0.2421	4.1667	0.1359
7	3.2276	0.4035	8.0000	1.2084
8	2.1303	0.0605	35.3333	0.0180
9	1.0490	0.0807	13.0000	0.0157
10	4.7600	0.2421	19.6667	0.6416
11	2.6224	0.0403	65.0000	0.0098
12	6.4553	0.1614	40.0000	0.3867
13	3.5100	0.4035	8.7000	1.3141
14	0.6455	0.1210	5.3333	0.0218
15	1.2104	0.2824	4.2857	0.2220
16	0.5648	0.0403	14.0000	0.0021
17	20.5761	0.2421	85.0000	2.7732
18	1.4121	0.1210	11.6667	0.0476
19	1.8962	0.1412	13.4286	0.0870
20	3.0662	0.1614	19.0000	0.1837
21	1.1297	0.1210	9.3333	0.0381
22	3.8732	0.2421	16.0000	

SAMPLE : F3 EEH, INC (CHRYSOTILE)

FIBER CONCENTRATION BY NUMBER PER CUBIC METER : 0.23E+05
FIBER CONCENTRATION BY MASS, PER CUBIC METER : 0.000 GRAMS*10^-6
AIR VOL. : 6120.0 LITERS
GRID SQUARES COUNTED : 60

DESCRIPTIVE STATISTICS

NO. OBS. = 13

VARIABLE	MEAN	VARIANCE	STANDARD DEVIATION	STANDARD ERROR
1 LENGTH	0.13655E+01	0.60032E+01	0.24512E+01	0.67983E+00
2 WIDTH	0.44354E-01	0.33669E-03	0.18349E-01	0.50892E-02
3 ASPECT RATIO	0.23527E+02	0.84632E+03	0.29092E+02	0.80686E+01
4 MASS	0.14677E-01	0.14274E-02	0.37781E-01	0.10479E-01

	SKEWNESS	KURTOSIS	MAX	MIN	RANGE
1	0.25474E+01	0.53790E+01	0.92794E+01	0.16140E+00	0.91180E+01
2	0.41959E+00	-0.12150E+01	0.80700E-01	0.20200E-01	0.60500E-01
3	0.23311E+01	0.45584E+01	0.11500E+03	0.50000E+01	0.11000E+03
4	0.27098E+01	0.60308E+01	0.13900E+00	0.20000E-03	0.13880E+00

SAMPLE : F3 EEH, INC (CHRYSOTILE)

	LENGTH	WIDTH	ASPECT RATIO	MASS
1	9.2794	0.0807	115.0000	0.1390
2	0.6852	0.0605	10.0000	0.0051
3	0.3631	0.0202	12.8571	0.0007
4	2.2593	0.0605	37.3333	0.0190
5	0.8473	0.0282	30.0000	0.0016
6	0.2421	0.0282	8.5714	0.0004
7	0.2017	0.0403	5.0000	0.0000
8	0.1614	0.0202	8.0000	0.0002
9	0.6859	0.0403	17.0000	0.0026
10	1.5735	0.0605	26.0000	0.0133
11	0.6455	0.0605	10.6667	0.0054
12	0.3229	0.0282	11.4286	0.0006
13	0.5648	0.0403	14.0000	0.0021

C

SAMPLE : C1 EEH, INC (CHRYSOTILE)

FIBER CONCENTRATION BY NUMBER PER CUBIC METER : 0.16E+05
FIBER CONCENTRATION BY MASS, PER CUBIC METER : 0.000 GRAMS*10+-6
AIR VOL. : 3419.0 LITERS
GRID SQUARES COUNTED : 60

DESCRIPTIVE STATISTICS

NO. OBS. = 6

VARIABLE	MEAN	VARIANCE	STANDARD DEVIATION	STANDARD ERROR
1 LENGTH	0.53793E+00	0.21273E-01	0.14585E+00	0.59544E-0
2 WIDTH	0.28883E-01	0.41522E-04	0.64437E-02	0.26306E-0
3 ASPECT RATIO	0.19262E+02	0.38060E+02	0.61693E+01	0.25186E+0
4 MASS	0.11800E-02	0.31600E-06	0.56214E-03	0.22949E-0

	SKEWNESS	KURTOSIS	MAX	MIN	RANGE
1	0.64757E+00	-0.11933E+01	0.68590E+00	0.28240E+00	0.40350E+00
2	0.51031E+00	-0.90794E+00	0.40300E-01	0.20200E-01	0.20100E-01
3	-0.53253E+00	-0.10234E+01	0.24206E+02	0.10000E+02	0.14206E+02
4	0.28710E+00	-0.14695E+01	0.20000E-02	0.50000E-03	0.15000E-02

SAMPLE : C1 EEH, INC (CHRYSOTILE)

	LENGTH	WIDTH	ASPECT RATIO	MASS
1	0.5245	0.0403	13.0000	0.0020
2	0.6859	0.0282	24.2857	0.0013
3	0.2824	0.0282	10.0000	0.0005
4	0.4841	0.0202	24.0000	0.0005
5	0.6052	0.0282	21.4286	0.0011
6	0.6455	0.0282	22.8571	0.0012